

## **AC 2008-2784: SUITABILITY OF AN UNDERGRADUATE CURRICULUM IN BIOMEDICAL ENGINEERING FOR PREMEDICAL STUDY**

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## **Suitability of an Undergraduate Curriculum in Biomedical Engineering for Premedical Study**

We sought to determine whether our Biomedical Engineering (BME) basic sciences curriculum would be accepted as fulfilling the *de facto* basic science requirements for admission to medical school, with a particular emphasis on our internal biology curriculum. 119 domestic medical schools were surveyed. Overall, 90% of responding medical schools responded favorably to our BME undergraduate biology curriculum. Data from MCAT scores and admissions rates support the conclusion that our program of study, and by implication that of many other BME programs, meets the requirements for medical school admissions without compromising the rigor of the engineering curriculum or requiring additional coursework beyond organic chemistry. Advanced physiology and cell biology lectures and labs are of key importance.

### **Introduction**

Academic advising for biomedical engineers presents special challenges, given the wide range of careers, graduate and professional education options that are open to them. Biomedical engineering (BME) programs generally find that a large portion of their graduates are bound for medical school. Anecdotally, it is often claimed that BME is superior as a pre-medical course of study to traditional pre-medical majors in academic preparation<sup>1</sup>, or when measured in admission rates. Indeed, the field is rife with claims of supra-normal medical school admissions rates, with some program web sites claiming medical school admission rates of up to 90%.

Defensible quantitative data on the admission rate to medical schools of BME graduates is lacking. So too are concrete demonstrations that BME programs are truly meeting the needs of pre-medical students and the educational expectations of medical schools. Are BME programs generally meeting the educational expectations of medical schools without overloading pre-med students with additional coursework? To what extent are additional biology and chemistry courses needed to meet those requirements? Are BME majors indeed matching or exceeding the MCAT scores and admission rates of other engineering and non-engineering majors?

We sought to answer these questions for our undergraduate program in BME at the University of Virginia (UVa).

### **Our pre-medical curriculum**

The biomedical engineering degree program requires 126 credit hours of coursework spanning the humanities, social sciences, mathematics, science, and engineering. During the first year of study all engineering students enroll as undifferentiated engineering students. Students select their major at the end of the first year. Once in the program, students work with their advisors to craft a program of study that includes 16 elective courses. The curriculum therefore offers ample room to customize study to students' interests and career goals. One objective we had in designing our curriculum was to make it possible to complete typical pre-med math/science

requirements without dedicating the entire elective structure toward meeting pre-med requirements. We assumed that these science requirements include:

1. Two semesters of physics with lab
2. Two semesters of chemistry with lab
3. Two semesters of calculus
4. Two semesters of organic chemistry with lab
5. Two semesters of biology with lab

A physical science sequence includes one semester of general inorganic chemistry and a two-course sequence in general physics that takes the student from classical mechanics to electromagnetic waves. The chemistry course and the physics courses have associated laboratories. The curriculum also requires a science elective, generally taken in the first year, which must be chosen from a short list of courses approved by the engineering school. The list includes biology, chemistry, materials science, and information science. Students who have expressed an interest in medical school are advised to take the second semester of general chemistry as their elective.

Required mathematics courses include calculus through multivariate, differential equations and a course in probability and statistics. Together, these fill the above requirements 1-3.

Students in our program are also required to choose two technical electives from any engineering, mathematics, or science course at the 200-level or above. Pre-med students typically fill this elective sequence with the lecture portions of organic chemistry I and II. The labs are generally taken as 6 credits of “unrestricted electives” out of the 12 credits available completing the above requirement 4.

Elective sequences in humanities and engineering-related social-science and communication courses are also required. These fulfill the humanities requirements of most medical schools.

Many undergraduate BME programs require general biology, and still more incorporate their own biology-based courses, variously including cell, molecular, and systems physiology along with relevant labs. These courses may provide a background in basic science and laboratory techniques comparable to traditional biology curricula, even if more focused on human physiology and pathology.

Undergraduate BME majors at UVa are required to take a three semester sequence of:

1. Physiology I, which includes cardiovascular, pulmonary and muscular systems;
2. Physiology II, including renal, blood, endocrine, gastrointestinal, and CNS; and
3. Cell and Molecular Biology, including the cellular basis of immunity and disease.

Students are also required to take a rigorous, two semester integrated lab sequence<sup>2</sup> in which they learn state of the art techniques including:

1. Cell culture
2. Fluorescence microscopy
3. Real-time PCR
4. Reconstituted contractile systems
5. Tissue engineering scaffolds
6. Ultrasound imaging
7. Microfluidics
8. Tissue biomechanics

Students must complete three BME electives, many of which have a strong biology focus (e.g. tissue engineering). We also require our majors to take an introductory course in BME design, a rigorous BME-based systems analysis course, a course in computational techniques in BME, and biomechanics.

We will not focus on the various other requirements of our degree program (e.g. the major design experience) because they do not directly address pre-med educational requirements, though they are certainly of value <sup>1</sup>.

### **The medical school point-of-view**

At present, our undergraduate majors struggle to fit general biology and lab into our already demanding engineering curriculum, yet it is typically assumed that general biology and lab is required by medical schools for admission (requirement 5). We *argue* that our courses in physiology, cell and molecular biology, and advanced laboratory techniques are more academically challenging than introductory biology courses and labs, yet provide similar background in basic science and techniques. However, medical schools might counter that they are not equivalent. For example, two topics that are not taught in our curriculum that are ordinarily taught in a standard two-semester biology and lab sequence are phylogeny and the biology of specific non-mammalian eukaryotic genera. Neither do we teach ecology and evolutionary biology, though these are not universally covered in freshman biology courses. Bacterial and viral biology are covered in our cell and molecular biology course, though in specific rather than broad terms.

We sought to determine whether our BME biology curriculum, and by implication those of other departments with similar course structures, would be accepted by medical schools as fulfilling the *de facto* requirement of one year of biology with lab.

Survey packets were sent to the admissions dean or director of admissions at 119 medical schools. The packets included: 1) a cover letter stating the intent of the survey, 2) single page syllabi of our cell and molecular biology, physiology and laboratory courses, and 3) a survey instrument to determine whether our cell, molecular, and systems physiology lecture and lab sequence would fulfill the basic requirements of biology courses for admission to their program, or whether a general biology sequence would also be required.

1. Does our cell, molecular, and systems physiology lecture sequence appear to fulfill the basic requirements of biology courses for admission to your program? (Yes or No)
2. For admission to your program, would you require a two-semester sequence of general biology lecture in addition to our cell, molecular, and systems physiology lecture sequence? (Yes, No or Recommended but not required)
3. Does our two-semester integrated lab sequence appear to fulfill the basic expectations and requirements of biology lab courses for admission to your program? (Yes or No)
4. For admission to your program, would you require a two-semester general biology lab sequence in addition to our integrated lab courses? (Yes, No or Recommended but not required)

An optional, open-ended question was also included, reading “Please write any other comments you may have on the back of this sheet or on a separate page. We are particularly interested in your views on whether our course and lab content is overly specific or general, and how that content compares to other comparable courses from other schools.” The cover letter assured respondents of confidentiality.

The survey generated a 60% response rate. Responses were stripped of identifying information and the results were tallied (see table). The overwhelming majority of respondents (nearly 89%) would *not* require our BME majors to take 2 semesters of general biology lab because our BME laboratories would suffice. Still another 4% would only “recommend but not require” taking general biology lab. Further, the majority of respondents (74%) would *not* require our BME majors to take 2 semesters of general biology lecture. Two semesters of physiology together with cell and molecular biology would suffice. Still another 17% would only “recommend but not require” taking general biology lecture courses. The free-responses were also interesting, and are addressed in subsequent sections. Overall, 90% of responding medical schools responded favorably to our BME undergraduate biology curriculum. As a result, we now advise our undergraduate BME majors that they do not have to take general biology or its associated labs to be prepared for medical school.

<b>Biology (BIOL) lecture and lab requirement</b>	<b>Percent (and number) of total survey responses</b>
Survey not applicable. No specific course requirements	2.9% (2)
Fulfills lecture and lab.	71.4% (50)
”Recommends but does not require” BIOL lecture. Fulfills lab.	11.4% (8)
“Recommends but does not require” BIOL lecture. “Recommends but does not require” BIOL lab.	4.3% (3)
Does <i>not</i> fulfill lecture. Fulfills lab.	2.9% (2)
“Recommends but does not require” BIOL lecture. Does <i>not</i> fulfill lab.	1.4% (1)
Does <i>not</i> fulfill lecture or lab.	5.7% (4)
<b>Total</b>	100.0% (70)

### **Pre-medical student achievement**

Whether or not medical schools endorse ours or any pre-med curriculum, admission to medical school ultimately depends on student performance. One of the primary questions posed by medical schools in the free-response section of the survey was whether our students would perform comparably on the MCATs to students who had completed a traditional pre-med basic science curriculum.

To answer this question, pre-graduation exit interviews and a web-based survey were used to obtain students’ self-reported MCAT scores and the status of their medical school applications process. The survey netted a 65% response rate. Of those who responded, 54% report that medical school is their top-choice post-graduation plan. However, there is a significant negative correlation (by Pearson’s and Kendall’s  $\tau_b$ ) between this fraction and student rank, meaning that

the fraction of students specifying medical school as their top-choice plan falls at a rate of ~ 9% per year as students progress through the curriculum (see table).

	Standing (year in program)		
	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>
Med school top-choice	62.5%	51.4%	43.8%

We compared our data on MCAT scores and admissions to statistics from US medical schools available from the American Association of Medical Colleges (AAMC)<sup>3</sup>. In the physical sciences, the total (VR+PS+BS) national MCAT score for medical school applicants in 2007 was  $29.6 \pm 3.75$  (standard deviation, found by propagating the error from individual scores) for 4,798 total students. For matriculants coming from physical science programs (which includes all engineering graduates), the total score was  $32 \pm 3.1$  for 2,291 students. For all matriculated students regardless of undergraduate major (numbering 17,759) it was  $30.8 \pm 3.1$ .

Approximately 60% of our current students participated in the online survey, and nearly comprehensive data was available from 2006 and 2007 graduating 4<sup>th</sup> years. In aggregate they had a mean MCAT total score of  $32.6 \pm 4.9$  (SD, N=35). This is significantly higher than the national average for physical science applicants to medical school, and for all matriculants in medical schools.

Accurate numbers on the *rate* of matriculation into medical school are difficult to obtain, for a variety of reasons. The principal reason is that many students take one or more years between undergraduate and medical school study to work, volunteer, or attend graduate school. In fact, the national average age of entering first year medical students was 24 in 2007<sup>4</sup>, suggesting that the majority spent two or more years engaged in other pursuits prior to matriculation. In our program, while 44% of the current 4<sup>th</sup> year students list medical school as their post-graduation plan, only 33% have actually applied. Longitudinal studies of graduates are notoriously difficult; thus much of the data on the remaining students is lost.

Nonetheless, amongst our current 4<sup>th</sup> year students, 56% of those applying to medical schools report having been accepted as of this writing (January, 2008). This compares favorably to the 47.7% nationwide average rate of acceptance of students from physical science majors<sup>3</sup>. An additional 38% have not yet heard of their acceptance or rejection. Combined with students who take a year or more between graduation and medical school matriculation, this will raise the rate of acceptance to greater than 56%.

## Conclusions and recommendations

We conclude that our undergraduate program in BME, with the simple addition of organic chemistry as an elective, meets the course requirements for medical school admissions, with no detriment to performance on the MCAT. While there was little concern regarding coverage of chemistry, organic chemistry, math and physics, the question remained whether a sequence of physiology, cell biology and associated advanced lab work would adequately substitute for the general biology courses that are generally expected of pre-meds. Our data suggests that such a sequence, common in BME programs, does in fact meet this expectation. Quoting a free-

response given by one medical school's Dean of Admissions,

“The courses listed actually exceed our requirements, and given the nature of these courses students would be better prepared for medical school with their courses than with one semester Biology with Lab component.”

This opinion, however, was not universal. Some schools responded with blanket statements that “general biology” or “organismic equivalents” are required. Another free-response is particularly worthy of note: “Do not assume that all medical schools have the same admissions requirements.” While it is true that medical schools have come to expect a standard array of basic science courses prior to matriculating, it is also true that some medical schools indicate having *no* requirements of particular classes; the MCAT is their principal measure of mastery of basic sciences. Indeed we have seen no evidence amongst our graduates that *any* medical schools reject students for lack of a particular undergraduate class.

One reason for this may be reflected in another free-response: “Be certain that this plan of study is strongly endorsed by UVa's premed advisor. Med schools are guided by that endorsement.” Most institutions have the equivalent of an office of pre-professional studies. We work closely with advisors in our office and provide paragraphs for inclusion in their letter of endorsement that explains our policy and practice in biology education. When non-standard biology, chemistry or physics courses are substituted in the curriculum, BME programs should take care to work with the school's or university's pre-med advisor to explain these deviations from a traditional pre-med curriculum.

### **Bibliography**

1. Jendrucko, R. J. and Wasserman, J. F. (2002) "Optimization of Undergraduate BME Curricula for Students Seeking Careers in Clinical Medicine." Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition: Session 2109-
2. Allen, T. E. and Blackman, B. R. (2007) "Integrative Design and Experimental Analysis: A Yearlong Laboratory Course in Biomedical Engineering." Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition: Session 1803-
3. AAMC. 9-25-2007 "MCAT and GPAs for Applicants and Matriculants to U.S. Medical Schools by Primary Undergraduate Major, 2007." <http://www.aamc.org/data/facts/2007/mcatgpabymaj07.htm> Accessed 1-16-2008
4. AAMC. 9-25-2007 "Age of Applicants to U.S. Medical Schools at Anticipated Matriculation by Hispanic or Latino Ethnicity, Non-Hispanic or Latino Race, and Sex, 2003-2007." <http://www.aamc.org/data/facts/2007/age0307.htm> Accessed 1-16-2008